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Nakamura et al.

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(54) **TRANSFORMER, LOUDSPEAKER DEVICE, LOUDSPEAKER NETWORK, AND LOUDSPEAKER SYSTEM**

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(51) **Int. Cl.**[7] **H04R 29/00**
(52) **U.S. Cl.** **381/59**; 381/116; 336/192
(58) **Field of Search** 381/407, 408, 381/409, 410, 191, 150, 174, 192, 116, 117, 111, 400, 59, 402, 181; 336/198, 208, 192, 222

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(57) **ABSTRACT**

A transformer includes a bobbin having a cavity, a primary winding wound around the bobbin, and a secondary winding wound around the bobbin and magnetically coupled with the primary winding. In the transformer, at least one of the primary winding and the secondary winding is divided into at least two portions which include a portion wound at an inside region of the transformer and a portion wound at an outside region of the transformer. Also, at least a portion of the other one of the primary winding and the secondary winding is wound between said at least two portions obtained by dividing the one of the primary winding and the secondary winding, and at least a portion of the cavity of the bobbin is used as a space to dispose another member therein.

12 Claims, 6 Drawing Sheets

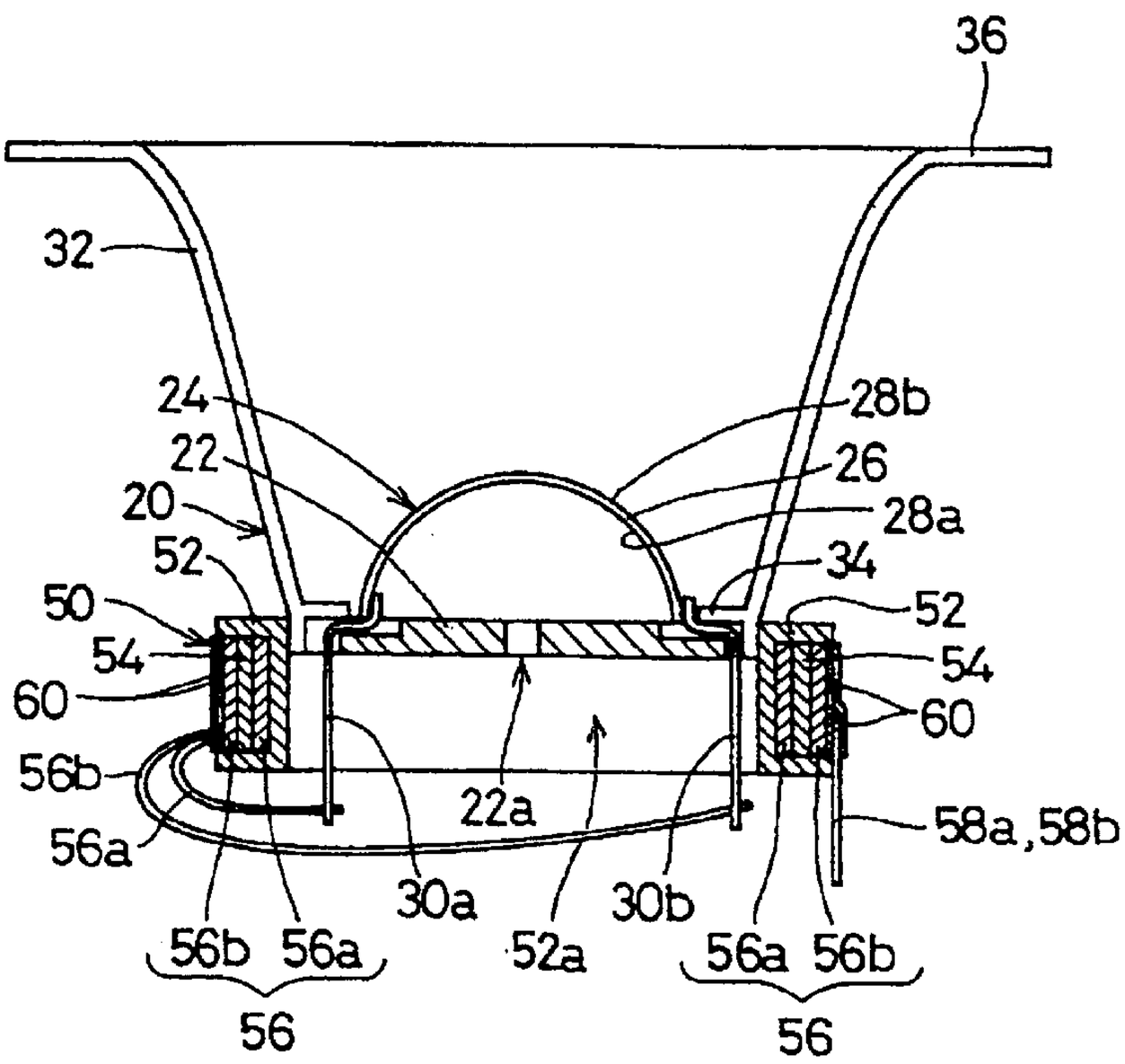


FIG. 1

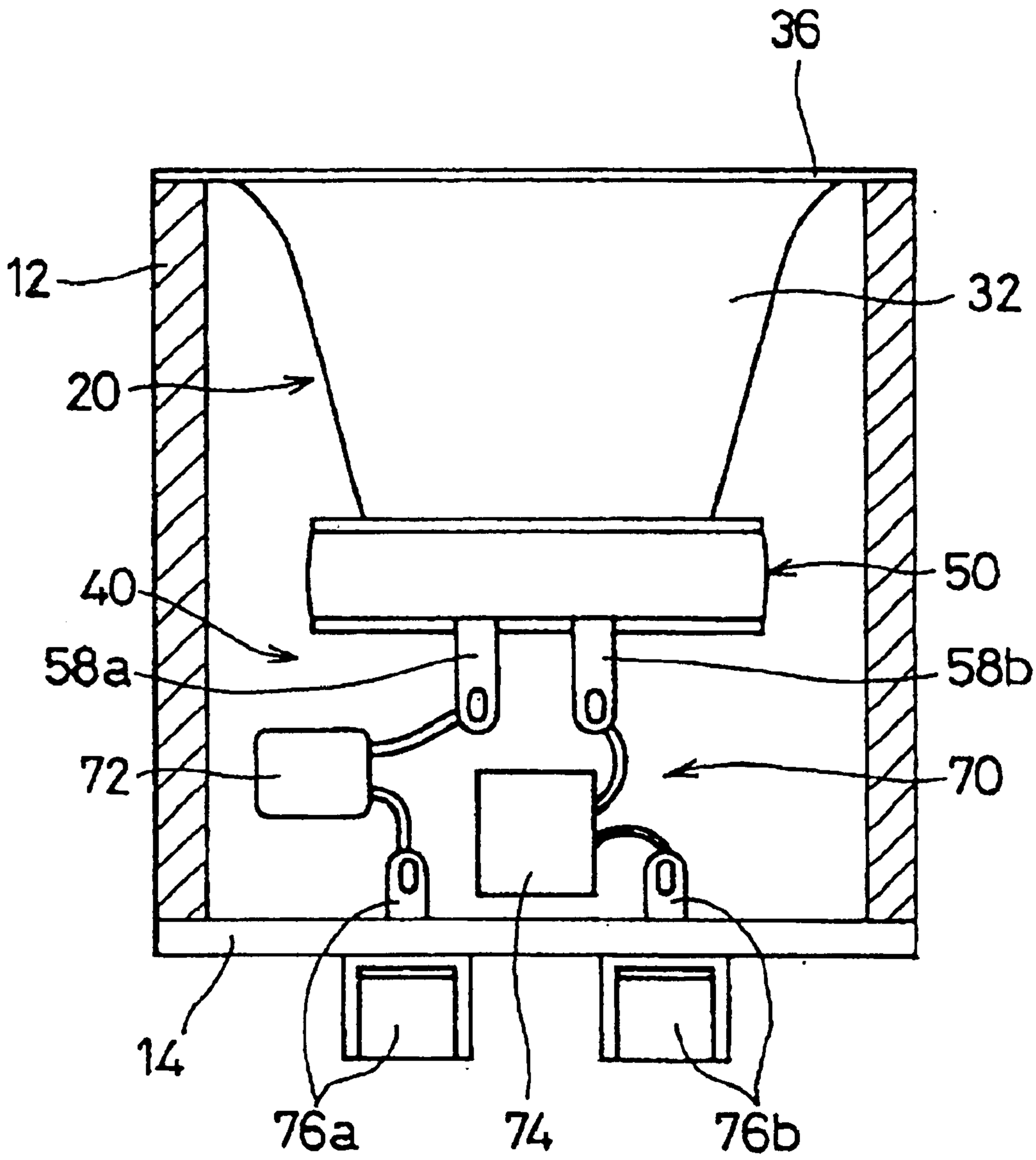


FIG. 2

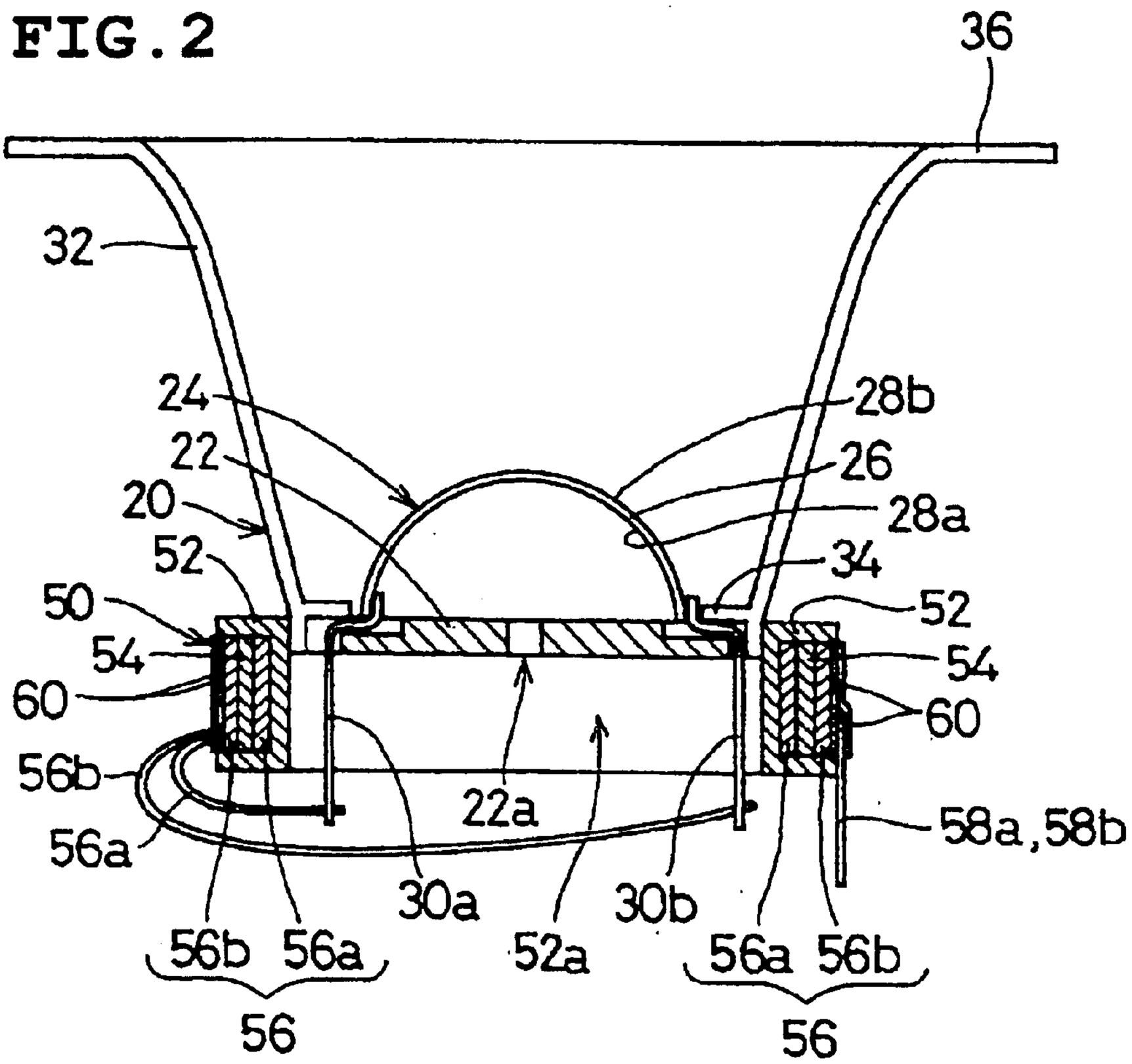

36
32
24
22
20
52
50
54
60
56b
56a
56
28b
26
28a
34
52
54
60
22a
58a, 58b
30a
30b
52a
56a 56b
56

FIG. 3

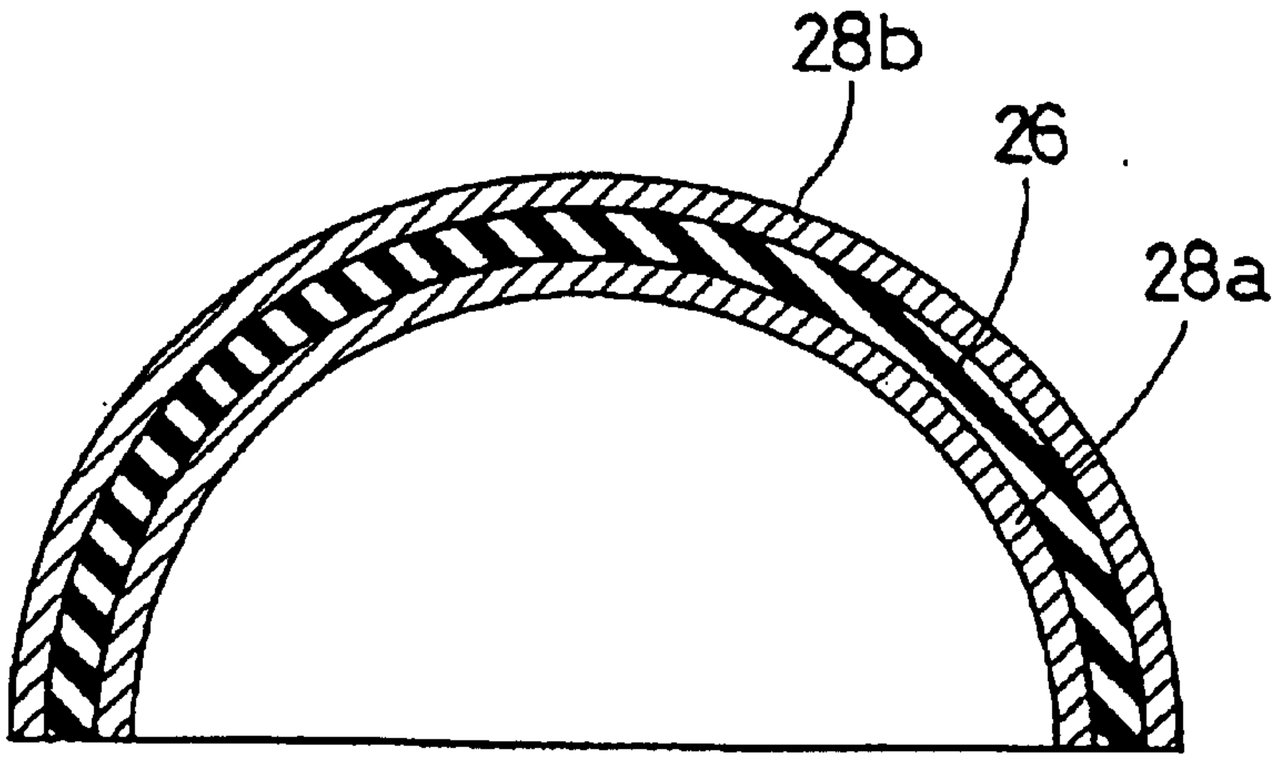

24
28b
26
28a

FIG. 4

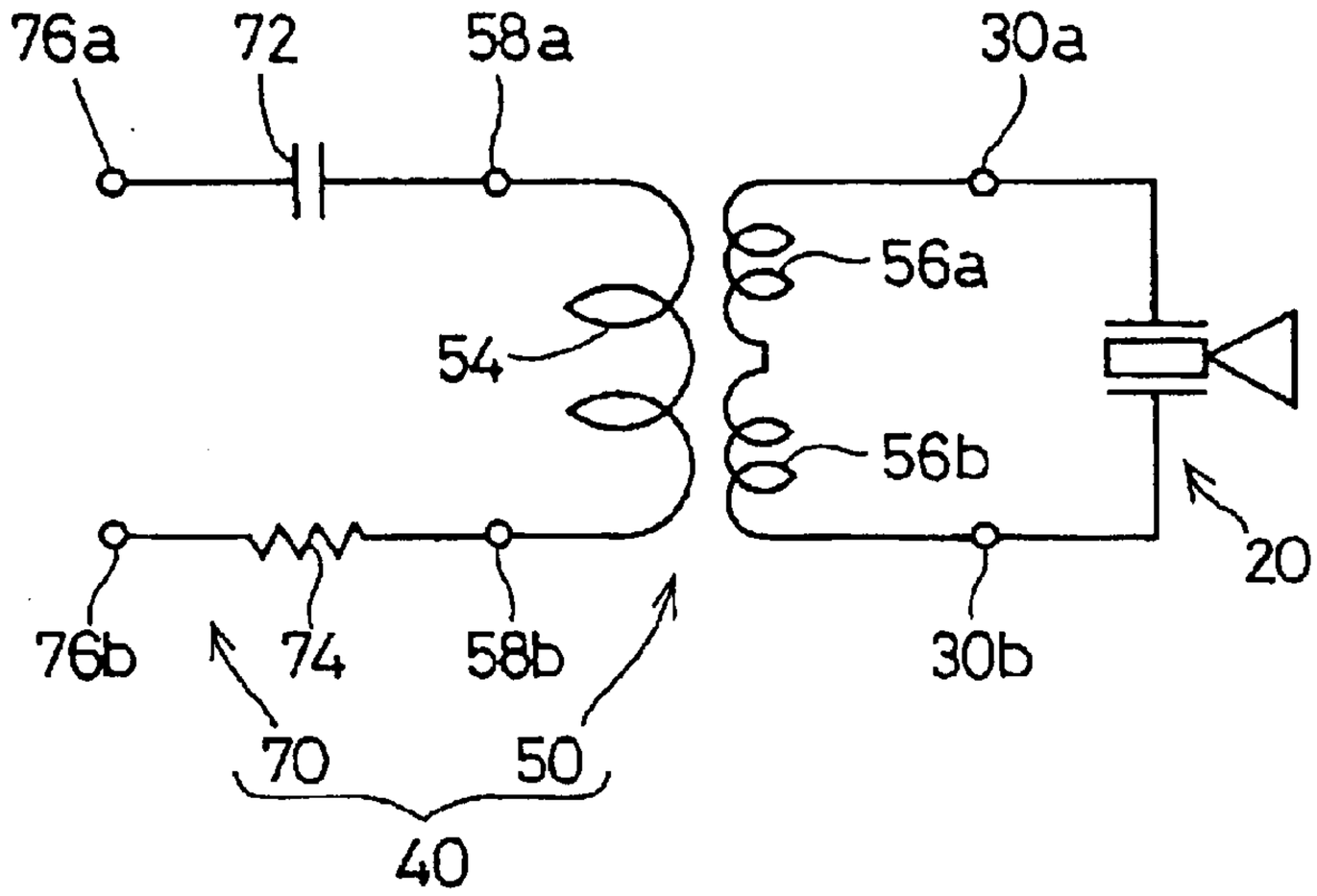

10
76a
72
58a
30a
56a
54
56b
20
76b
74
58b
30b
70
50
40

FIG. 5

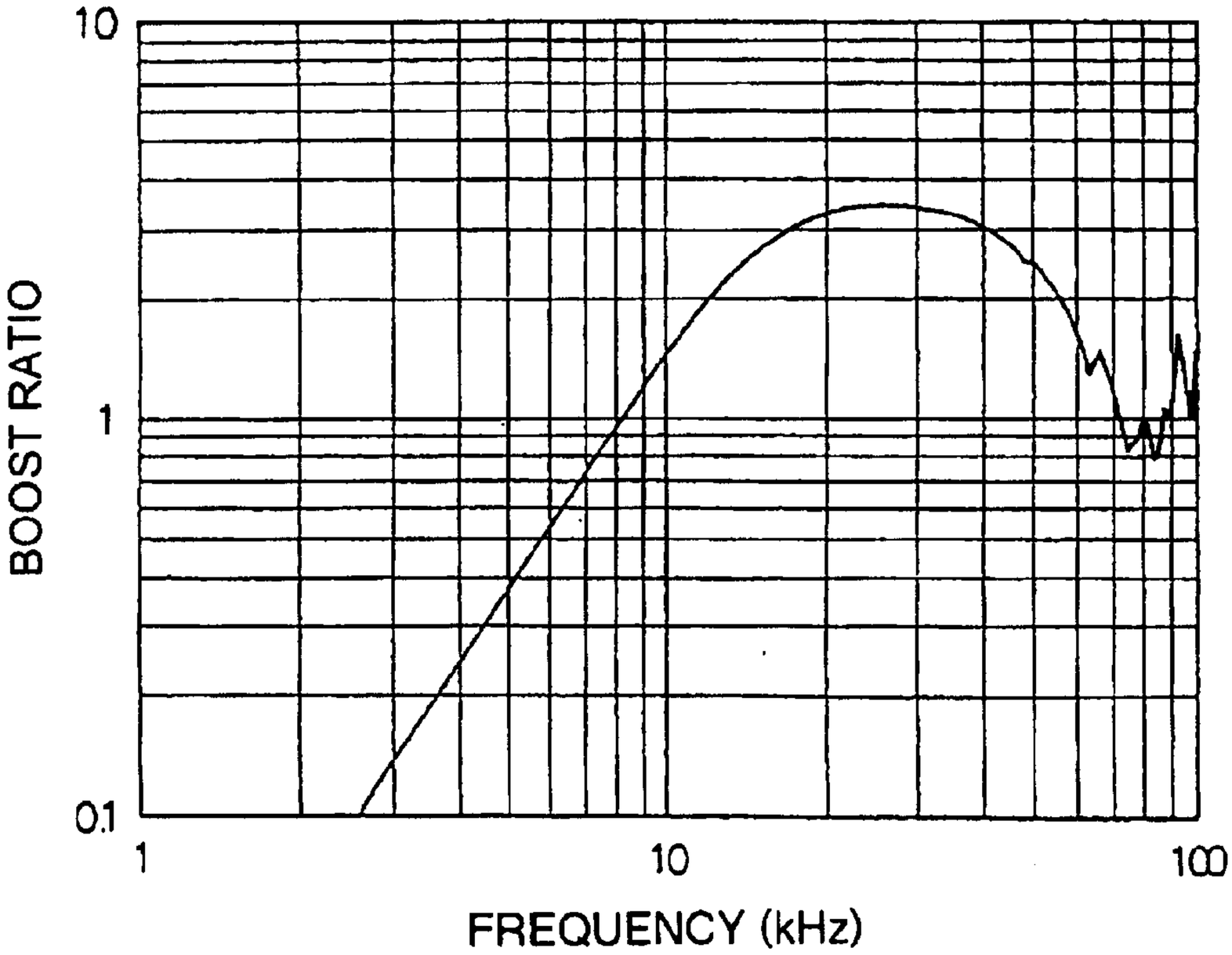

10
1
0.1
BOOST RATIO
1
10
100
FREQUENCY (kHz)

FIG. 6

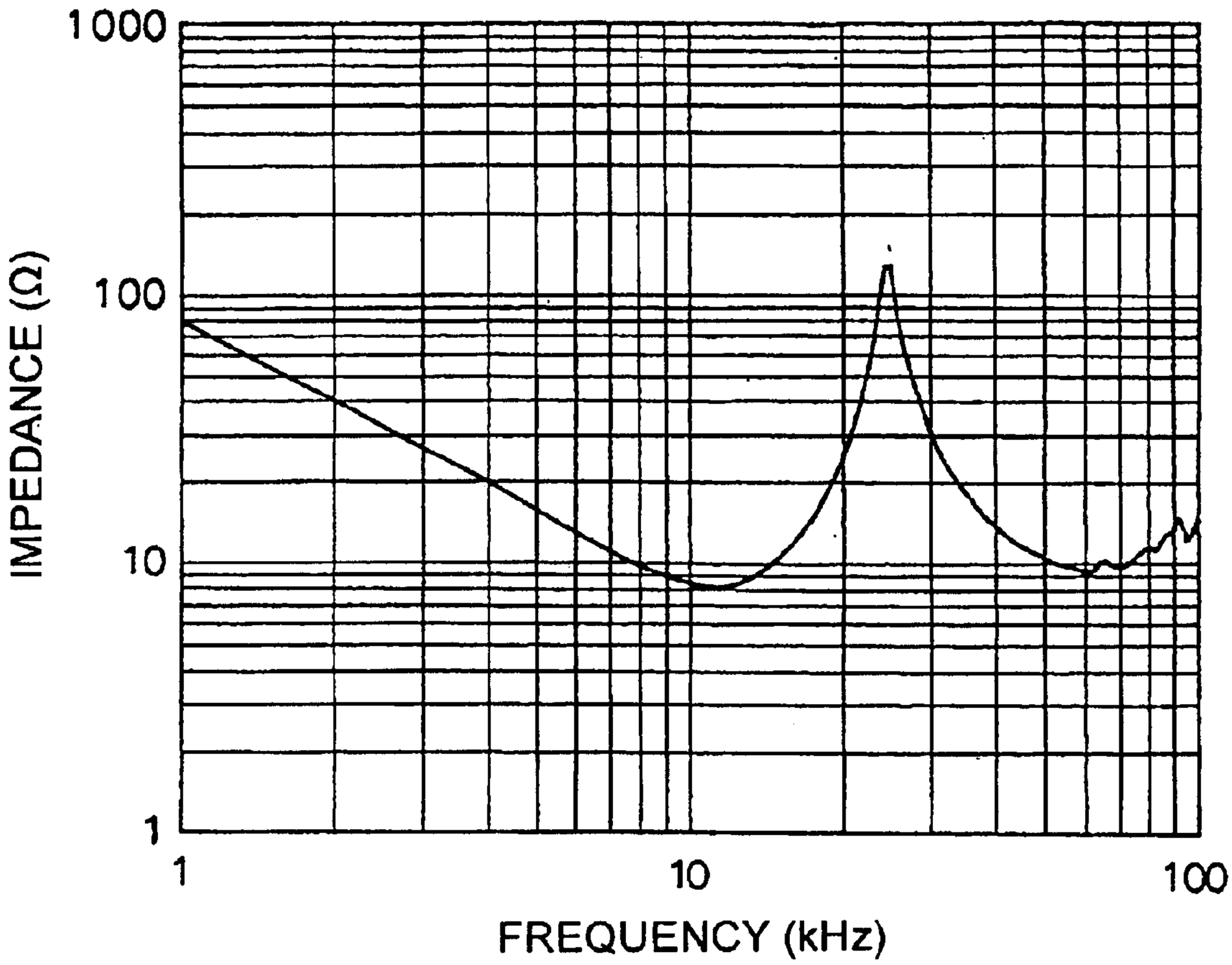


FIG. 7

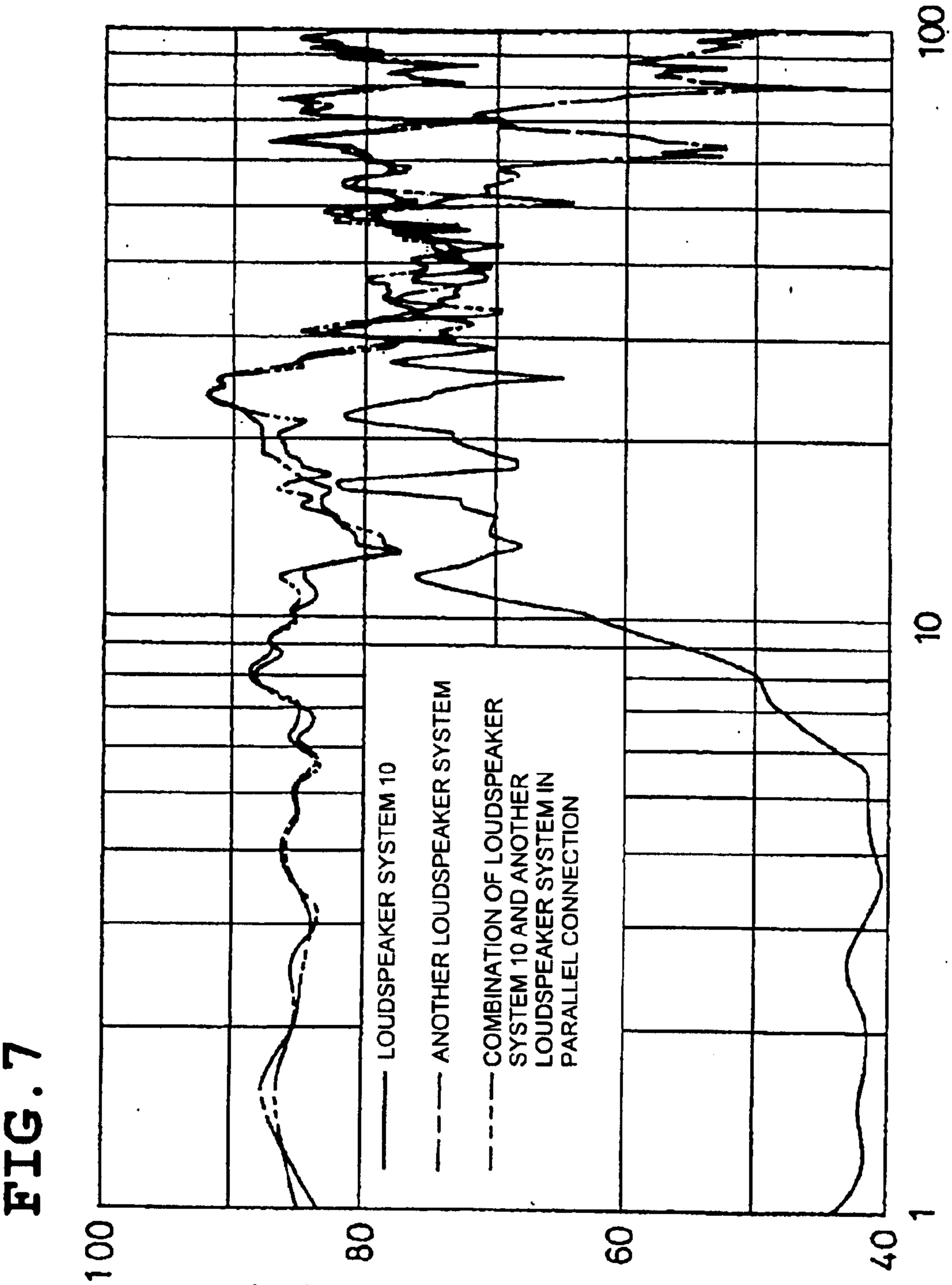
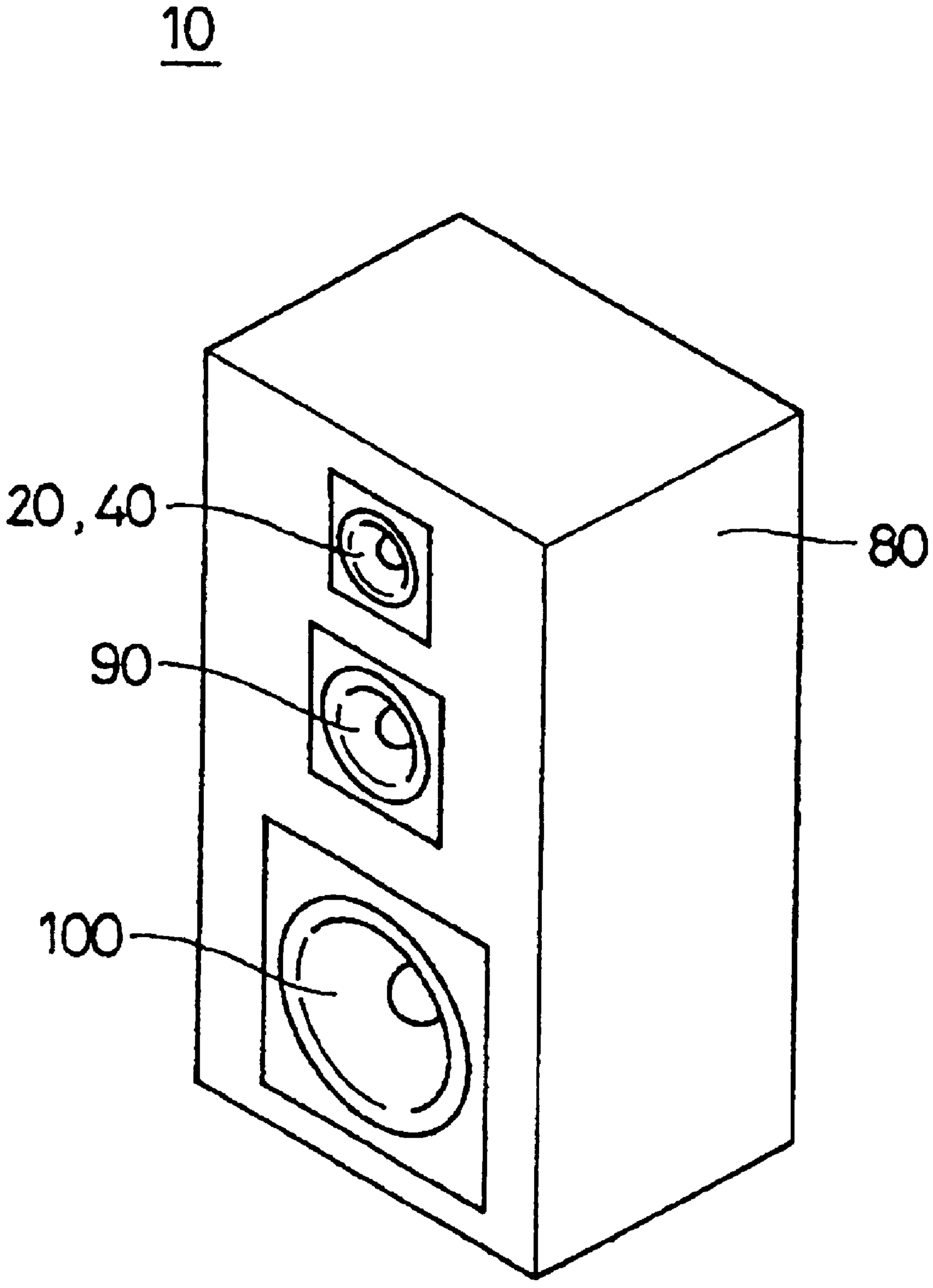

100
80
60
40
SOUND PRESSURE (dB)
100
10
1
FREQUENCY (kHz)
LOUDSPEAKER SYSTEM 10
ANOTHER LOUDSPEAKER SYSTEM
COMBINATION OF LOUDSPEAKER SYSTEM 10 AND ANOTHER LOUDSPEAKER SYSTEM IN PARALLEL CONNECTION

FIG. 8



TRANSFORMER, LOUDSPEAKER DEVICE, LOUDSPEAKER NETWORK, AND LOUDSPEAKER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to transformers, loudspeaker devices, loudspeaker networks, and loudspeaker systems, and more specifically relates to a transformer included in a piezoelectric loudspeaker, and to a loudspeaker device, a loudspeaker network, and a loudspeaker system that include the above-described transformer.

2. Description of the Related Art

A transformer for a conventional piezoelectric loudspeaker is constructed such that a primary winding and a secondary winding are wound around a bobbin and a core is inserted into the bobbin.

In the above-described transformer for the conventional piezoelectric loudspeaker, the transformer is expensive as well as heavy due to the use of the core. Accordingly, the removal of the core has been contemplated to produce an inexpensive and light-weight transformer. However, the removal of the core decreases the magnetic coupling strength between the primary winding and the secondary winding. Moreover, to reduce the size of the piezoelectric loudspeaker, it is desirable to provide another member, such as a portion of the loudspeaker, within the above-described transformer of the conventional piezoelectric loudspeaker. These points also apply to a loudspeaker device, a loudspeaker network, and a loudspeaker system that include the transformer for the conventional piezoelectric loudspeaker.

SUMMARY OF THE INVENTION

In order to overcome the problems described above, preferred embodiments of the present invention provide an inexpensive, compact, and lightweight transformer which has strong magnetic coupling between a primary winding and a secondary winding, and which can hold another member therein.

Further, preferred embodiments of the present invention provide a loudspeaker device, a loudspeaker network, and a loudspeaker system which include a transformer that is inexpensive, compact, and lightweight, and that has strong magnetic coupling between a primary winding and a secondary winding, and which has another member disposed therein.

According to a first preferred embodiment of the present invention, a transformer including a bobbin having a cavity, a primary winding wound around the bobbin, and a secondary winding wound around the bobbin and magnetically coupled with the primary winding is provided. In the transformer, at least one of the primary winding and the secondary winding is divided into at least two portions which include a portion wound at the inside and a portion wound at the outside, at least a portion of the other one of the primary winding and the secondary winding is wound between said at least two portions obtained by dividing the one of the primary winding and the secondary winding, and at least a portion of the cavity of the bobbin is used as a space to accommodate another member therein.

According to another preferred embodiment of the present invention, a loudspeaker device includes a transformer as described in the previous paragraph, and a loudspeaker, connected to the transformer, and including a sound-producing body having a piezoelectric body. In the loudspeaker device, at least a portion of the loudspeaker is provided in the cavity of the bobbin.

In the loudspeaker device according to another preferred embodiment of the present invention, the loudspeaker has a horn for conducting sound waves transmitted from the sound-producing body, one end of the horn is inserted into the cavity of the bobbin, and the bobbin of the transformer is mounted on the horn.

According to another preferred embodiment of the present invention, a loudspeaker network includes a transformer having the features of the preferred embodiment described above and an impedance network connected to the transformer.

According to a further preferred embodiment of the present invention, a loudspeaker system includes a loudspeaker device according to a preferred embodiment described above, and a loudspeaker network according to the preferred embodiment described above. In the loudspeaker device, the transformer of the loudspeaker device includes the transformer of the loudspeaker network.

Since there is no core used in the transformer, the transformer is inexpensive as well as lightweight.

Furthermore, in the transformer according to preferred embodiments of the present invention, since at least one of the primary winding and the secondary winding is wound between at least two portions obtained by dividing the other one of the primary winding and the secondary winding, the magnetic coupling between the primary winding and the secondary winding of the transformer is stronger than a transformer constructed by winding the entire primary winding and the winding the entire secondary.

Also, in the transformer according to preferred embodiments of the present invention, since a portion of the cavity of the bobbin is used as a space for having another member disposed therein, another member, such as an end portion of the horn of the loudspeaker, can be disposed therein.

Other features, characteristics, arrangements and advantages of the present invention will become more apparent from the detailed description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration showing one example of a loudspeaker system according to a preferred embodiment of the present invention;

FIG. **2** is an illustration showing a loudspeaker device of the loudspeaker system shown in FIG. **1**;

FIG. **3** is a sectional view showing a vibrator of a piezoelectric loudspeaker included in the loudspeaker system shown in FIG. **1**;

FIG. **4** is a circuit diagram of the loudspeaker system shown in FIG. **1**;

FIG. **5** is a graph showing frequency characteristics of the boost ratio of a loudspeaker network used in the loudspeaker system shown in FIG. **1**;

FIG. **6** is a graph showing frequency characteristics of the impedance of the loudspeaker network used in the loudspeaker system shown in FIG. **1**;

FIG. **7** is a graph showing frequency characteristics of the sound pressure of the loudspeaker system shown in FIG. **1**; and

FIG. **8** is a perspective view of another preferred embodiment of a loudspeaker system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is an illustration showing one example of a loudspeaker system according to a preferred embodiment of the present invention. FIG. **2** is an illustration showing a loudspeaker device of the loudspeaker system. A loudspeaker system **10** shown in FIG. **1** preferably includes a substantially cylindrical casing **12** made of synthetic resin, or other suitable material. One end of the casing **12** is open while the other end has a disk-shaped lid **14** adhered thereto.

The casing **12** has a piezoelectric loudspeaker **20** mounted therein as a tweeter. The piezoelectric loudspeaker **20** includes a disk-shaped supporting member **22** as shown in FIG. **2**. A hole **22***a*, serving as a so-called "air vent" is provided at the approximate center of the supporting member **22**. One major surface of the supporting member **22** has a substantially hemispherical vibrator **24** with a diameter of about 20 mm attached thereto. The vibrator **24** functions as a sound-producing body and includes a substantially hemispherical vibrating body **26** which is made of a piezoelectric material, such as a piezoelectric ceramic, or other suitable piezoelectric material, polarized in the thickness direction, as shown in FIG. **3**. Electrodes **28***a* and **28***b* are provided on the internal surface and external surface of the vibrator **24**, respectively.

As shown in FIG. **2**, input terminals **30***a* and **30***b* each have one end thereof soldered to the electrodes **28***a* and **28***b* of the vibrator **24**, respectively. Furthermore, a horn **32** made of a synthetic resin, or other suitable material, is mounted around the supporting member **22**.

The horn **32** is configured so that the width thereof gradually increases from one end **34** towards the other end **36**. The end **34** of the horn **32** includes a step and the other end **36** of the horn **32** includes a flange. The end **34** of the horn **32** is adhered to the surrounding of the supporting member **22**, thus securing the input terminals **30***a* and **30***b* between the end **34** of the horn **32** and the surrounding of the support member **22**, as shown in FIG. **2**. The other end **36** of the horn **32** is adhered to one end of the casing **12** as shown in FIG. **1**, and supports the piezoelectric loudspeaker **20** in the casing **12**. In this piezoelectric loudspeaker **20**, by inputting a signal across the input terminals **30***a* and **30***b*, the vibrator **24** vibrates, and a sound is produced from the horn **32**.

Furthermore, the loudspeaker system **10** includes a loudspeaker network **40**. The loudspeaker network **40** includes a transformer **50** and an impedance network **70**.

As shown in FIG. **2**, the transformer **50** includes a substantially cylindrical bobbin **52** made of a synthetic resin, or other suitable material. The bobbin **52** has a cavity **52***a* in the approximate center thereof. The nose of the end **34** of the horn **32** of the piezoelectric loudspeaker **20** is inserted into the cavity **52***a* of the bobbin **52**. Thus, the bobbin **52** is fixedly adhered around the end **34** of the horn **32**. In this case, not only the end **34** of the horn **32** but also the supporting member **22** of the piezoelectric loudspeaker **20** and middle portions of the input terminals **30***a* and **30***b* are provided in the cavity **52***a* of the bobbin **52**. A primary winding **54** and a secondary winding **56** are wound around this bobbin **52**. In this case, the secondary winding **56** is divided into two portions **56***a* and **56***b*. The portion **56***a* of the secondary winding **56**, the primary winding **54**, and the portion **56***b* of the secondary winding **56** are wound in that order around the bobbin **52**, such that the primary winding **54** is sandwiched between portions **56***a* and **56***b* of the secondary winding **56**. Furthermore, in the secondary winding **56**, one end of the portion **56***a* is connected to the input terminal **30***a* of the piezoelectric loudspeaker **20**, the other end of the portion **56***a* is connected to one end of the portion **56***b*, and the other end of the portion **56***b* is connected to the input terminal **30***b* of the piezoelectric loudspeaker **20**. That is, the ends of the secondary winding **56** are connected to the corresponding input terminals **30***a* and **30***b* of the piezoelectric loudspeaker **20**. The ends of the primary winding **54** are connected to corresponding terminals **58***a* and **58***b*. These terminals **58***a* and **58***b* are mounted via an insulating tape **60** on the portion **56***b* of the secondary winding **56**.

As described above, the loudspeaker device is constructed by combining the piezoelectric loudspeaker **20** and the transformer **50**.

As shown in FIG. **1**, the impedance network **70** includes a capacitor **72** of about 2 μF and a resistor **74** of about 6.7 kΩ, or other suitable capacitance and resistance. One end of the capacitor **72** and one end of the resistor **74** are connected to the two terminals **58***a* and **58***b* of the transformer **50**, respectively. The other end of the capacitor **72** and the other end of the resistor **74** are connected to two external terminals **76***a* and **76***b*, respectively. These external terminals **76***a* and **76***b* are mounted so as to penetrate the lid **14** of the casing **12**.

Therefore, this loudspeaker system **10** includes a circuit shown in FIG. **4**.

Since there is no core provided in the transformer **50** of the loudspeaker network **40**, the loudspeaker system **10** is inexpensive as well as lightweight.

Since the primary winding **54** is wound between the two portions **56***a* and **56***b* obtained by dividing the secondary winding **56** of the transformer **50** of this loudspeaker system **10**, the magnetic coupling between the primary winding **54** and the secondary winding **56** is stronger than the magnetic coupling between a primary winding and a secondary winding of a transformer constructed by winding the primary winding and the secondary winding in that order, such that the primary winding is not sandwiched between two portions of the secondary winding.

Furthermore, in this loudspeaker system **10**, the cavity **52***a* of the bobbin **52** of the transformer **50** is effectively used as a space for disposing the supporting member **22** and the input terminals **30***a* and **30***b* of the piezoelectric loudspeaker **20**, and the end **34** of the horn **32**.

In this loudspeaker system **10**, as shown by frequency characteristics of the boost ratio of the loudspeaker network **40** in FIG. **5**, the boost ratio is high in the high frequency band. Accordingly, this loudspeaker system **10** produces an outstanding tweeter because high sound pressure is obtained from the piezoelectric loudspeaker **20** in the high frequency band.

In this loudspeaker system **10**, the frequency characteristics of the impedance of the loudspeaker network **40** as shown in FIG. **6** illustrate that the impedance is high at portions of the low frequency band. Accordingly, when this loudspeaker system **10** is connected in parallel with another loudspeaker, such as a woofer, this loudspeaker system **10** performs very well because it does not practically affect a signal in the low frequency band. Frequency characteristics of sound pressures concerning this loudspeaker system **10**, another loudspeaker system, and the loudspeaker system obtained by connecting these systems in parallel are shown in FIG. **7**. According to the frequency characteristics shown in FIG. **7**, the other loudspeaker system does not have a very high sound pressure in the high frequency band. However, by connecting the loudspeaker system **10** in parallel with the

other loudspeaker system, the sound pressure is increased in the high frequency band while it is not substantially affected in the low frequency band.

In this loudspeaker system **10**, the end **34** of the horn **32** of the piezoelectric loudspeaker **20** is a node of the piezoelectric loudspeaker **20**. Since the loudspeaker device is constructed by mounting the transformer **50** at the end **34**, a loudspeaker device having a compact structure is produced, in which the transformer **50** does not substantially affect the vibration of the piezoelectric loudspeaker **20** and the space of the air-core unit of the transformer **50** (the cavity **52***a*) can be effectively utilized.

In this loudspeaker system **10**, since a core is not used in the transformer **50**, the inductance of the transformer **50** is greatly reduced, and the desired inductance is obtained in the high frequency band. Accordingly, the transformer **50** is well-suited for use in the loudspeaker network **40**.

FIG. **8** is a perspective view showing another preferred embodiment of the loudspeaker system according to the present invention. A loudspeaker system **10** shown in FIG. **8** has the piezoelectric loudspeaker **20** and the loudspeaker network **40**, along with a midrange **90** and a woofer **100**, mounted in one casing **80**.

In the above described loudspeaker system **10**, unlike in the transformer **50** of the loudspeaker network **40** where the primary winding **54** is wound between the two portions **56***a* and **56***b* of the secondary winding **56**, the secondary winding **56** can be wound between two portions of the primary winding **54**. Alternatively, portions obtained by dividing each of the primary winding **54** and the secondary winding **56** into at least two portions may be alternately wound from among the primary winding portions and the secondary winding portions.

Although in the above-described loudspeaker system **10**, the supporting member **22** and the input terminals **30***a* and **30***b* of the piezoelectric loudspeaker **20** and the one end of the horn **32** are provided within the cavity **52***a* of the bobbin **52** of the transformer **50**, other members may also be disposed therein.

In the above-described loudspeaker system **10**, although the impedance network **70** including the capacitor **72** and the resistor **74** is provided, another impedance network may be used.

In the above-described loudspeaker system **10**, although the piezoelectric loudspeaker **20** is used, another type of loudspeaker may be used.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skill in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit of the invention.

What is claimed is:

1. A loudspeaker device comprising:

a transformer comprising:

a bobbin having a cavity;

a primary winding wound around said bobbin; and

a secondary winding wound around said bobbin and magnetically coupled with said primary winding; wherein

at least one of said primary winding and said secondary winding is divided into at least two portions which include a portion wound at an inside region of the transformer and a portion wound at an outside region of the transformer;

at least a portion of the other one of said primary winding and said secondary winding is wound between said at least two portions obtained by dividing the one of said primary winding and said secondary winding; and

at least a portion of said cavity of said bobbin is used as a space to dispose another member therein; and

a loudspeaker, connected to said transformer, and including a sound-producing body having a piezoelectric body; wherein at least a portion of said loudspeaker is provided in said cavity of said bobbin.

2. A loudspeaker device according to claim **1** wherein said loudspeaker includes a horn to conduct sound waves transmitted from said sound-producing body;

one end portion of said horn is inserted into said cavity of said bobbin; and

said bobbin of said transformer being mounted on said horn.

3. A loudspeaker network comprising:

a transformer according to claim **1**; and

an impedance network connected to said transformer.

4. A loudspeaker system comprising:

a loudspeaker device including a transformer having a bobbin having a cavity, a primary winding wound around said bobbin, and a secondary winding wound around said bobbin and magnetically coupled with said primary winding, wherein at least one of said primary winding and said secondary winding is divided into at least two portions which include a portion wound at an inside region of the transformer and a portion wound at an outside region of the transformer, at least a portion of the other one of said primary winding and said secondary winding is wound between said at least two portions obtained by dividing the one of said primary winding and said secondary winding, and at least a portion of said cavity of said bobbin is used as a space to dispose another member therein, said loudspeaker device being connected to said transformer, and including a sound-producing body having a piezoelectric body, at least a portion of said loudspeaker is provided in said cavity of said bobbin; and

an impedance network connected to said transformer.

5. A loudspeaker system according to claim **4**, wherein said loudspeaker includes a horn to conduct sound waves transmitted from said sound-producing body, one end portion of said horn is inserted into said cavity of said bobbin, and said bobbin of said transformer being mounted on said horn.

6. A loudspeaker device comprising:

a transformer comprising:

a bobbin having a cavity;

a primary winding wound around said bobbin; and

a secondary winding wound around said bobbin and magnetically coupled with said primary winding; wherein at least one of said primary winding and said secondary winding is divided into at least two portions which include a portion wound at an inside region of the transformer and a portion wound at an outside region of the transformer;

at least a portion of the other one of said primary winding and said secondary winding is wound between said at least two portions obtained by dividing the one of said primary winding and said secondary winding; and

wherein at least a portion of said cavity of said bobbin is used as a space to dispose another member therein; and

a loudspeaker, connected to said transformer, and including a sound-producing body having a piezoelectric body.

7. A loudspeaker device according to claim **6**, wherein at least a portion of said loudspeaker is provided in said cavity of said bobbin.

8. A loudspeaker device according to claim **6**, wherein said loudspeaker includes a supporting member, and said sound-producing body is mounted on said supporting member.

9. A loudspeaker device according to claim **8**, wherein said supporting member is disk-shaped and includes a hole in a approximate central portion thereof.

10. A loudspeaker device according to claim **6**, wherein said loudspeaker includes a horn to conduct sound waves transmitted from said sound-producing body, one end portion of said horn is inserted into said cavity of said bobbin, and said bobbin of said transformer is mounted on said horn.

11. A loudspeaker device according to claim **6**, wherein said loudspeaker includes a horn to conduct sound waves transmitted from said sound-producing body, and a supporting member, said horn being mounted on said supporting member, one end portion of said horn is inserted into said cavity of said bobbin, and said bobbin of said transformer is mounted on said horn.

12. A loudspeaker device according to claim **11**, wherein said loudspeaker further includes a plurality of input terminals connected to said sound-producing body, and each of said plurality of input terminals having a portion disposed between said horn and said supporting member.

* * * * *